MA-P11

Evaluation of EUV mask pattern inspection using DUV reticle inspection tool

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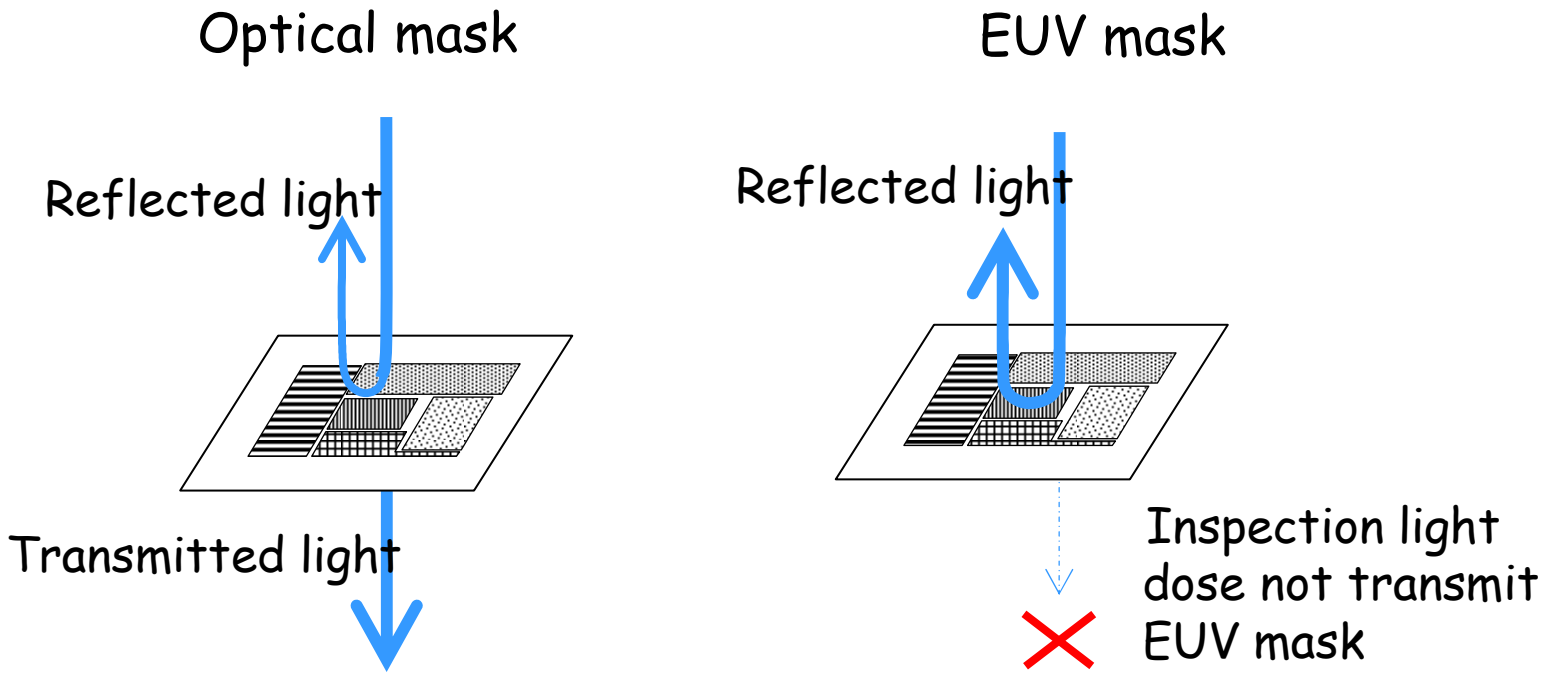
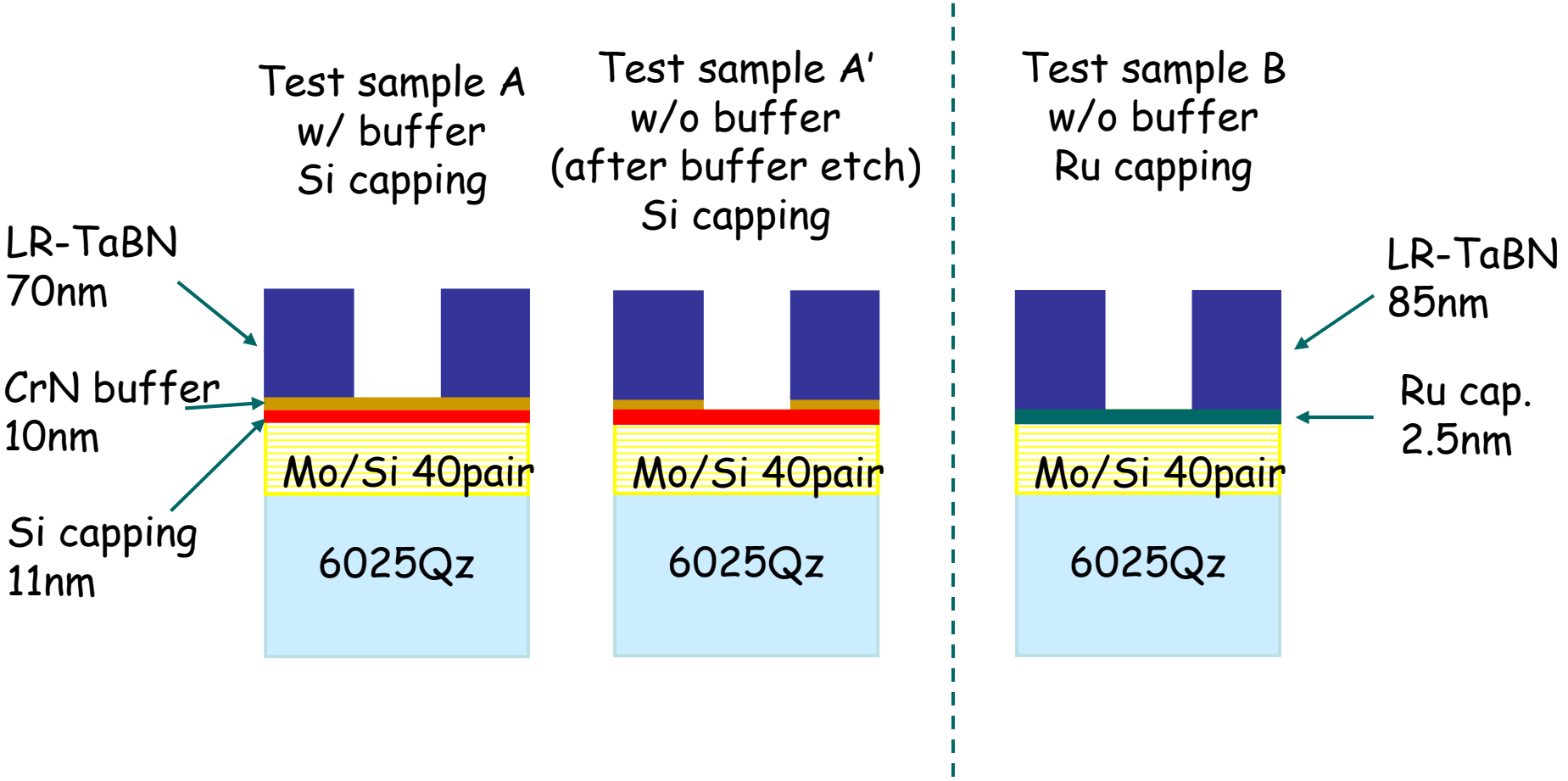
Introduction

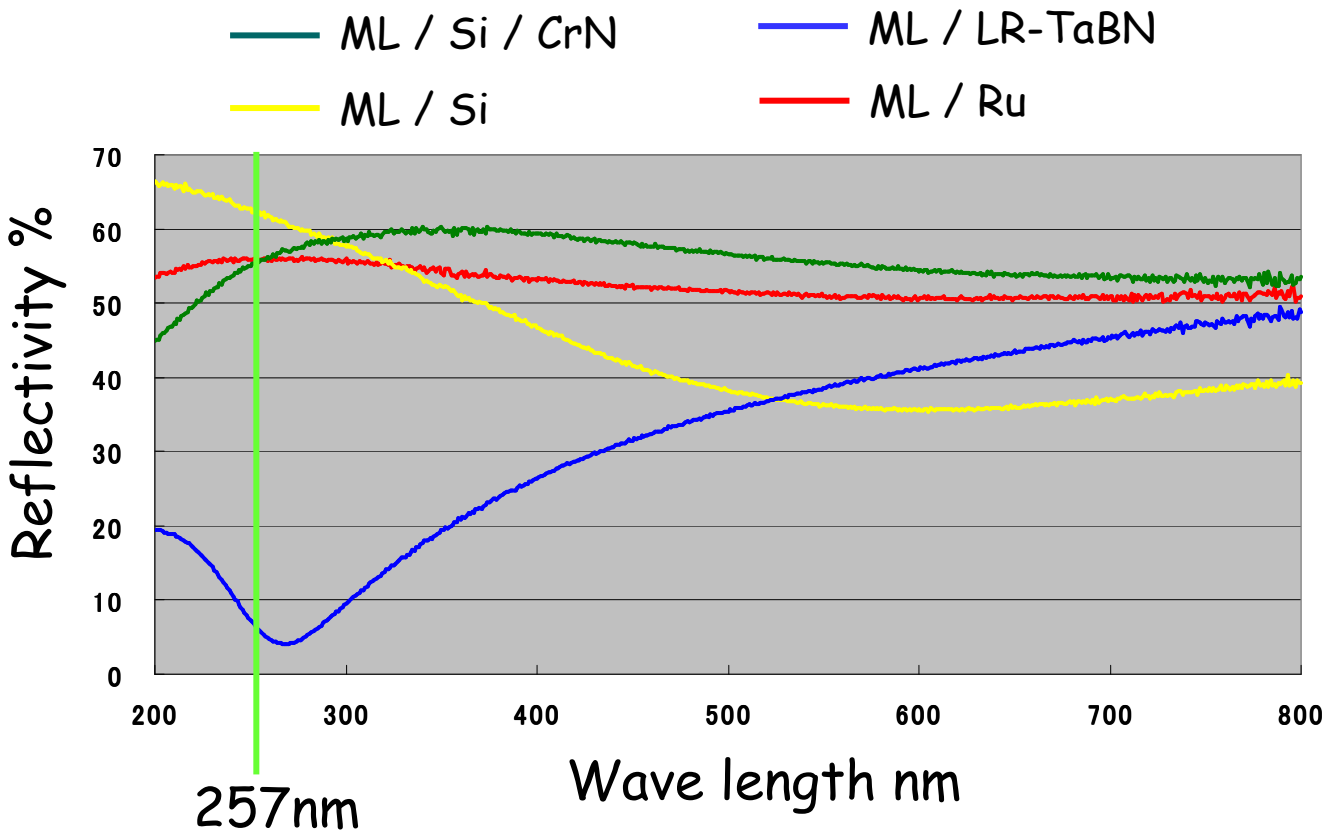
- **Differently from optical photomask, EUV mask defect inspection uses only reflected light**



Inspection test sample



Reflectivity curve of EUV mask



Courtesy of HOYA

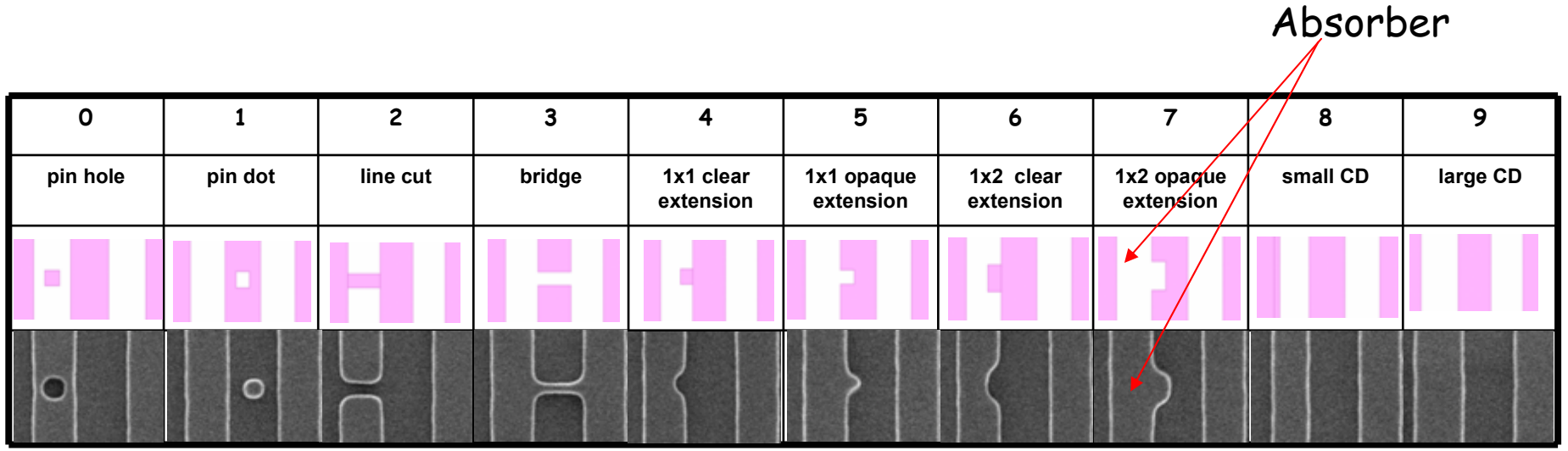
Optical property was optimized for defect inspection with 257nm wave length

Evaluation tool

- Program defect size measurement
  - CD-SEM
    : KLA 8250R
  - Pattern edge detection & area size measurement
    : In-house software
- Defect print simulation
  - Kirchhoff simulation.
- Inspection tool : KLA586
  - Wave length 257nm / Pixel size 90nm
  - DD / DB

Programmed defect

Resist patterning : 50kV EB writer with PCAR 300nm
Main pattern : 1:1 dense line
Main pattern size : hp 260nm/180nm @ mask



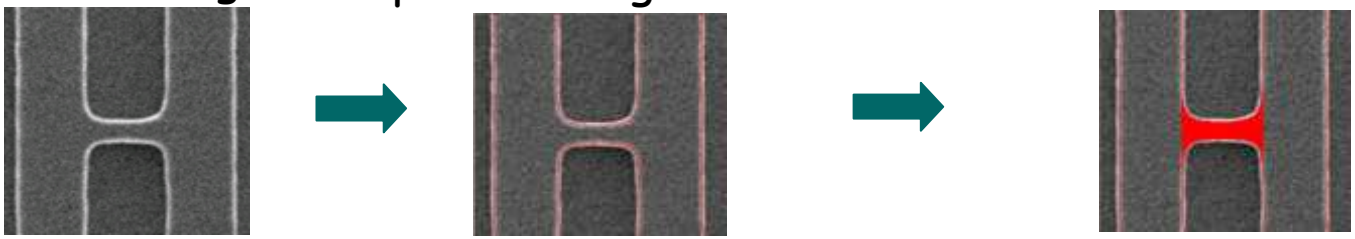
SEM images : main pattern size 260nm

Program defect size measurement

Defect size definition

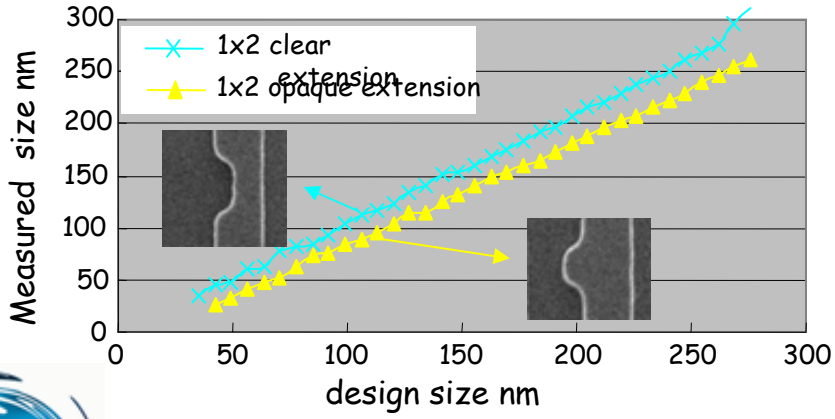
1. **Measured defect size = square root of area (nm)**

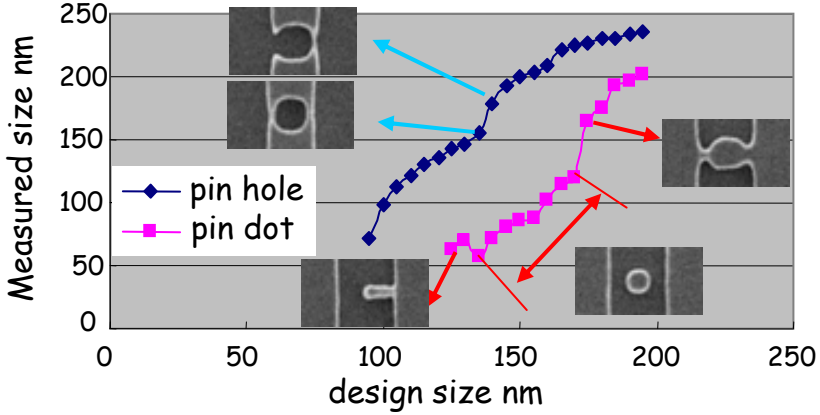
SEM image → pattern edge definition → area size measurement



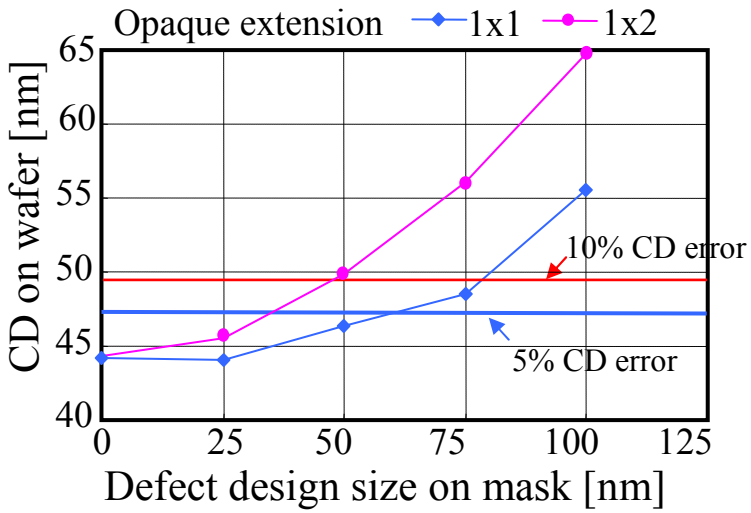
2. **CD error = |defect line CD - reference line CD|**

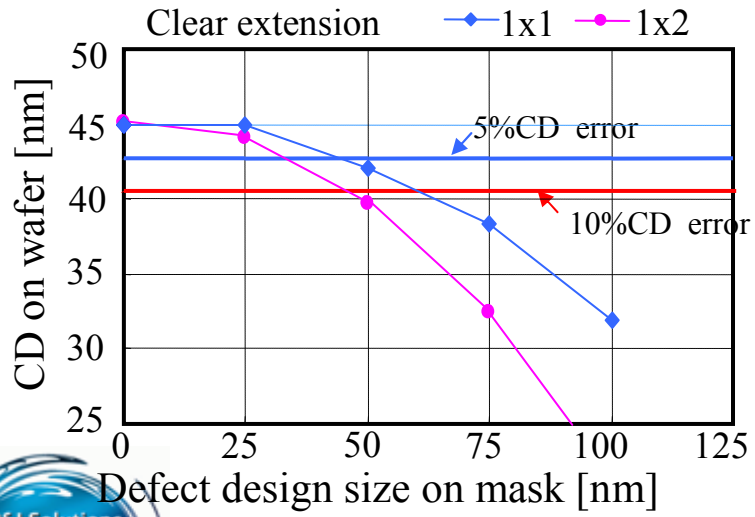
Defect size measurement results





Defect printability simulation sample

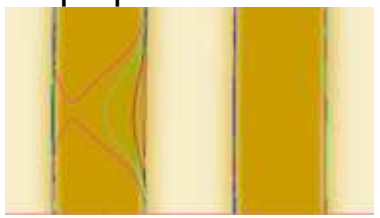




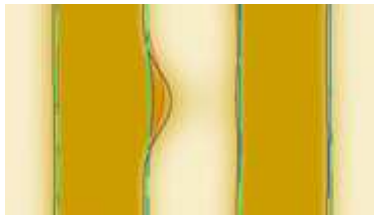
Optical image on wafer

1x1 opaque extension

1x2 opaque extension



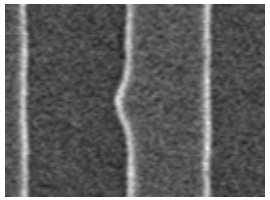
1x1 clear extension



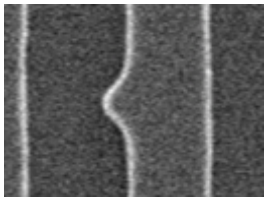
1x2 clear extension

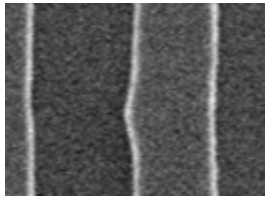
Programmed defect SEM image

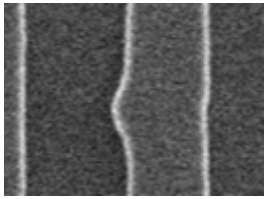
5% CD error

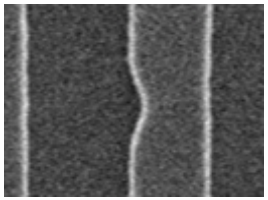


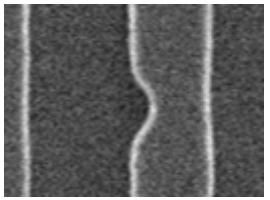
10% CD error

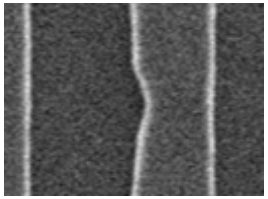


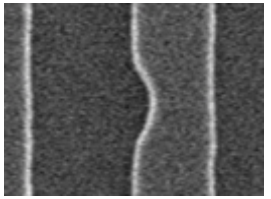










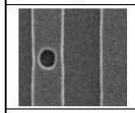
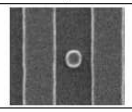
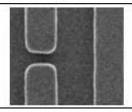
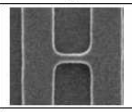
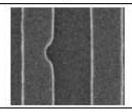
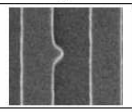
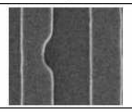
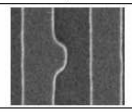
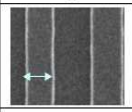
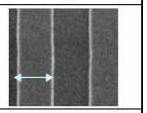


~hp 180nm l/s~

Defect inspection results

~Si cap / CrN buffer structure : 260nm hp ~

	sample	Mode	Tool	Pixel	Algorithm	Sensitivity	#runs
a	w/ bubber	DDR	KLA5X6	P90	UPA	high	5
b	w/ bubber	DBR	KLA5X6	P90	UPA	high	5
c	w/o buffer	DDR	KLA5X6	P90	UPA	high	5
d	w/o buffer	DBR	KLA5X6	P90	UPA	high	5

No	0	1	2	3	4	5	6	7	8	9
										
	pin hole	pin dot	line cut	bridge	1x1 clear extension	1x1 opaque exten	1x2 clear extension	1x2 opaque exten	small CD (line)	large CD (line)

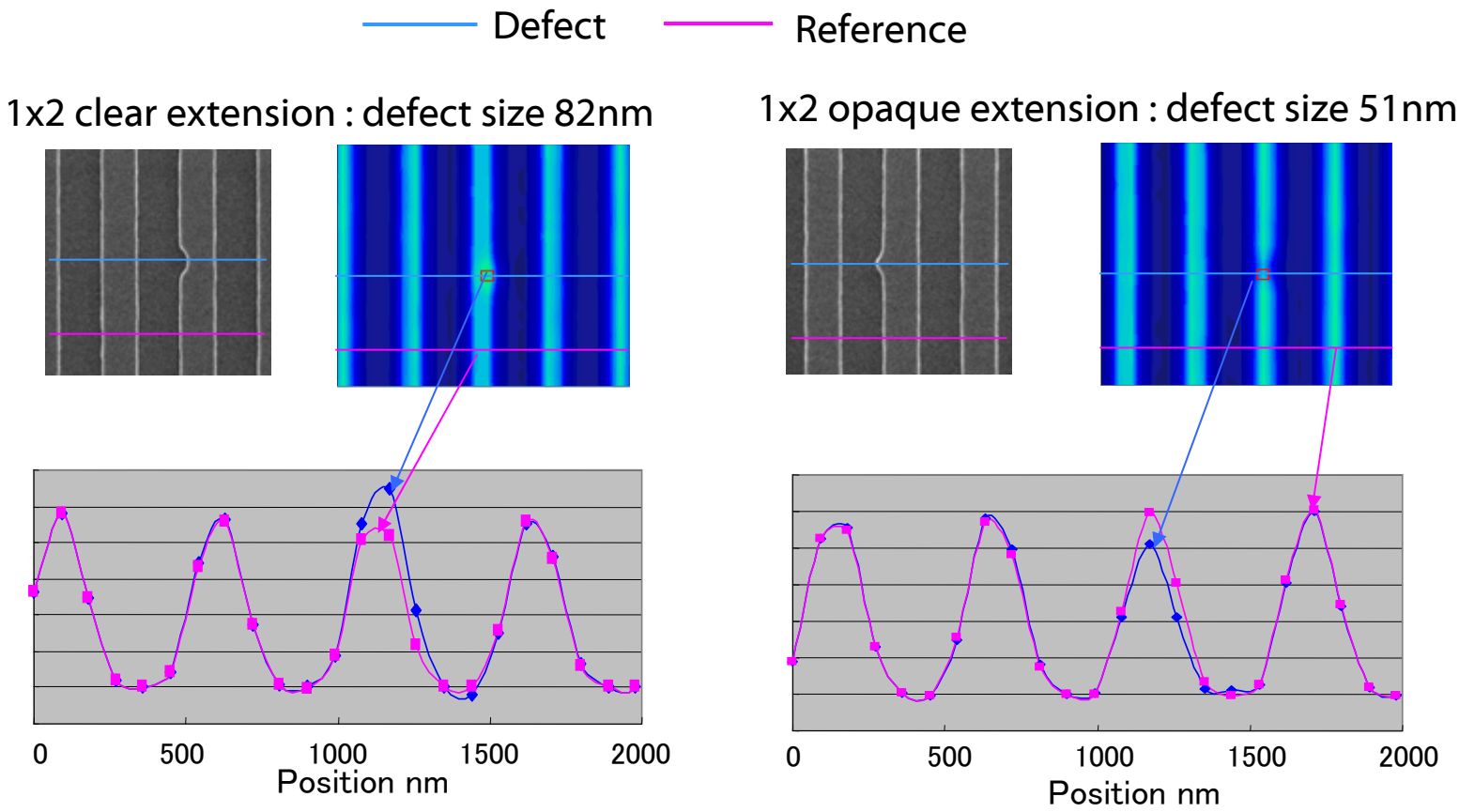
	pin hole					pin dot					line cut					bridge					1x1 clear extension					1x1 opaque exten					1x2 clear extension					1x2 opaque exten					small CD (line)					large CD (line)				
	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d	size	a	b	c	d
5											59.7										21.4										33.9										9.4					12.3				
6											77					26.5					24.8										45.1					25.6									11.9				
7											85.4					30.9					28.5										47.4					32.5					13.6					16.7				
8											96.6					31.9					42.2					18					61.3					41.3					17.2			40		16.5				
9											129					54					44.3					20.3					63.5					46.9					17.4					17.1				
10											151					61					53.6					30.8					77.5			40	40	50.9					20.6					19.8				
11											161			20		64		40			54.6					35.4					81.7			40	80	63.2					21.4					20.1				
12											164		60		40	64.9					69					41					84					72.4				40	26.3					24.1				
13											166					88.2					73.4					45.2					92.9					76.4					26.8					26.8				
14											175					98.9					78.1			60	20	50.4					103					84.3					28.8					28.4				
15											173					118					85.1	60		80		56.6					112					87.5					32					30.6				
16											180					129					85.6		80	20	60	59.5					116					95					33					30.6				
17											181					133					91.5					60.7				80	124					104					37.4					32.9				
18											186					138					93.9					66.1					134					114					38.7					37.4				
19	71.61										187					141					104					70.9					141					114					40.3					38.4				
20	98.7										190					150					109					74.7					150					126					39.4					40.0				
21	113										199					154					116					82.9					153					132					42.2					44.2				
22	121										198					164					121					83					160					139					46.3					44.4				
23	130										203					161					126					85.8					169					148					46.5					44.5				
24	135										205					167					134					94.7					175					152					50.6					51.0				
25	142					63					206					172					138					99.8					184					159					50.3					52.0				
26	146					69.3					210					178					141					107					192					163					53.8					53.3				
27	155					57.6					211					183					148					107					197					172					50.3					61.5				
28	179	60			20	70.9					215					187					152					112					206					181					59.3					55.1				
29	194					79.7					219					195					158					118					215					189					65.4					57.9				
30	200					85.4					220					197					164					123					220					196					62.8					61.1				
31	203					88					225					198					172					131																								
32	209					102					224					199					176					135																								
33	222					114					226					209					180					137																								
34	225					119					230					210					186					148																								
35	227					163					231					213					189					150																								
36	231					174					234					222					196					153																								
37	231					192					239					223					201					162																								
38	233					197					236					225					207					167																								
39	236					201					239					226					228					172					310					261					83.1					78.5				

5% CD error

10% CD error(by simulation)

Inspection sensitivity difference between w/ and w/o buffer pattern was not observed

Light intensity profile of defect



Good light intensity profile was obtained at 260nm pattern.

Defect inspection results

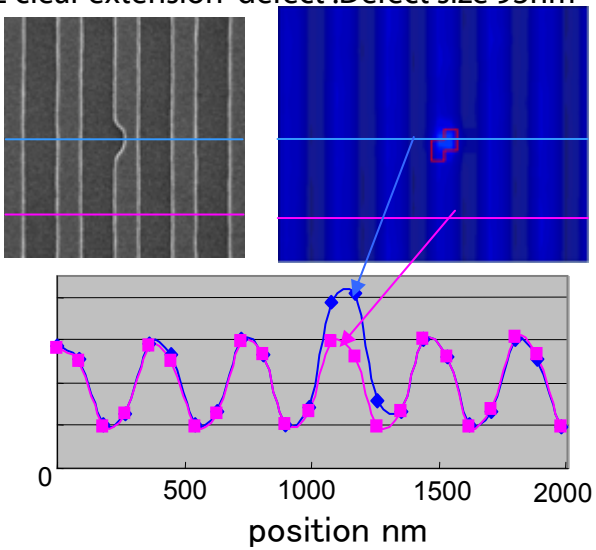
~Si cap / CrN buffer structure : 180nm hp ~

	sample	Mode	Tool	Pixel	Algorithm	Sensitivity	#runs
a	w buffer	DDR	KLA5X6	P90	UPA	high	5
b	w/o buffer	DDR	KLA5X6	P90	UPA	high	5

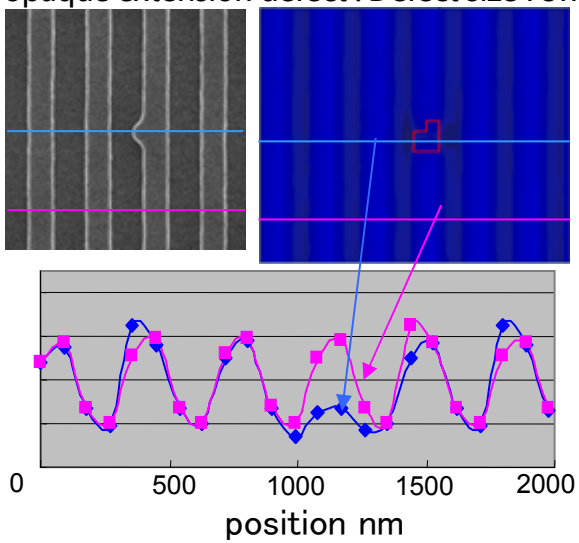
No	0			1			2			3			4			5			6			7			8			9		
	pin hole			pin dot			line cut			bridge			1x1 clear exter			1x1 opaque ex			1x2 clear exter			opaque exten			small CD			large CD		
	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b
0																									1.7			0.4		
1																									4.1			2		
2																									3.9			2.5		
3																									7.5			4.8		
4							50																		7.2			6.3		
5							71												38			24			11			11		
6							79			24			27						43			35			12			11		
7							94			32			37			16			58			34			15			14		
8							119			36			40			26			53			43			17			14		80
9							127			50			51			12			63			46			22	60	20	18	40	
10							131			54			55			28			73	20		58			22			21	80	
11							136			64			59			37			84			61			24			21		
12							142			75			61			38			92			72			27			26		
13							146			76			68			49			93			75			26			28		
14							148			103			76			50			103			84			30			29		
15							151			106			84			54			113			89			34			30		
16							152			120			87			58	60		120			98			33			32		
17	42						153			123			93			68			126			102			38			35		
18	137	40					155			126			104			67			133			116			38			39		
19	137						157			129			104			76			144			115			42			40		
20	145						159			135			112			78			149			124			44			39		
21	151			57			165			143			117			85			157			134			46			43		
22	152			74			170			141			123			86			162			138			48			43		
23	160			101			166			148			126			88														
24	161			119			170			147			149			100														
25	168			133			174			156			151			104														
26	169			141			174			159			161			109														
27	175			147			180			163			165			116														
28	176			153			175			166			172			122														
29	178			164			176			173			175			149														
30	179			165			182			174			178			158														

5% CD error
10% CD error
(by simulation)

1x2 clear extension defect :Defect size 93nm



1x2 opaque extension defect : Defect size 75nm



Defect inspection results

~ Ru Capping structure ~

~ 260 nm hp ~

	Mode	Pixel	Algorithm	Sensitivity	#runs
a	DDR	P90	UPA	high	10
b	DBR	P90	UPA	high	10

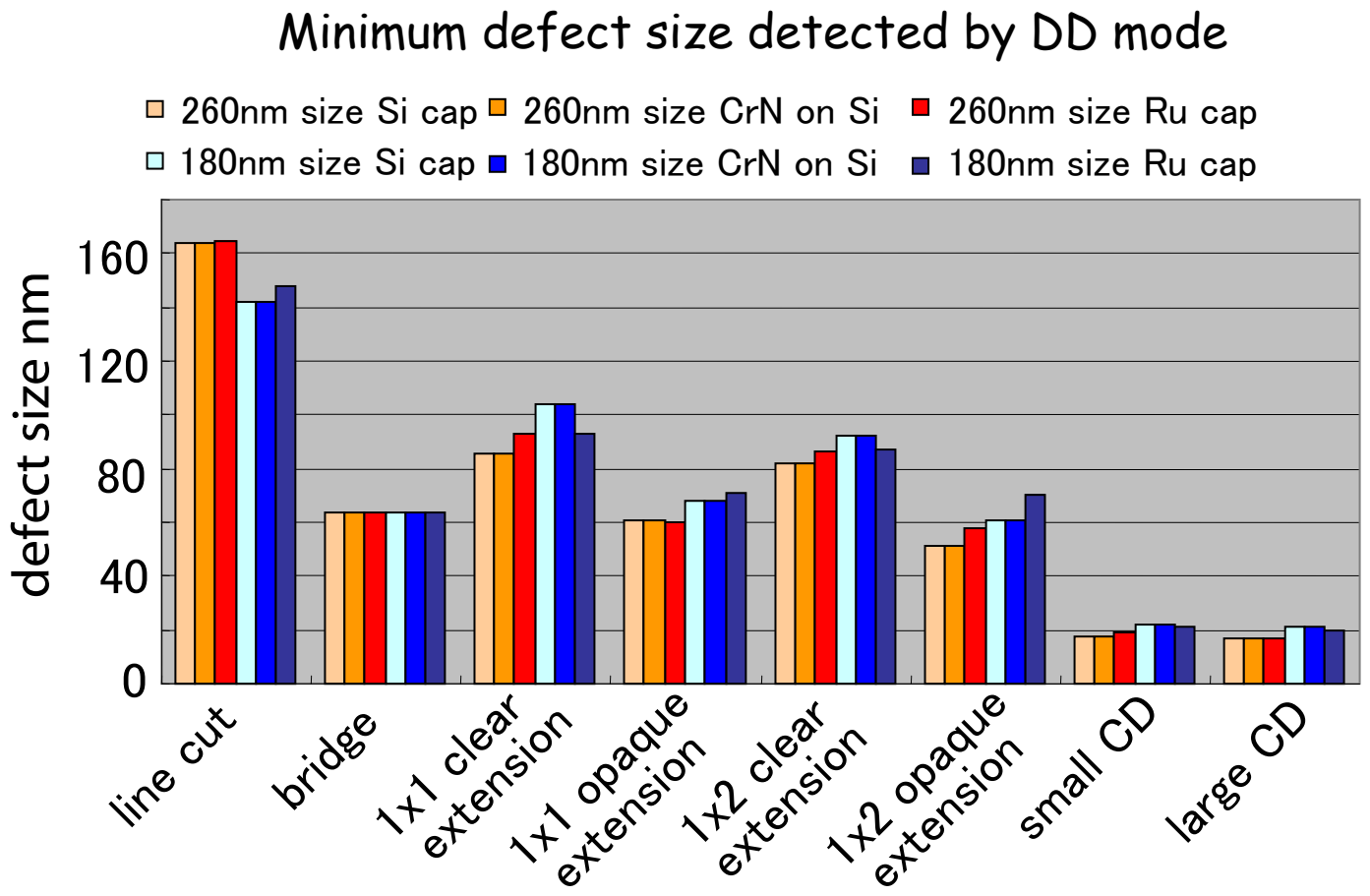
No	0			1			2			3			4			5			6			7			8			9		
																											
	pin hole			pin dot			line cut			bridge			1x1 clear extensi			1x1 opaque exte			1x2 clear extensi			2 opaque extensi			small CD			large CD		
	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b	size	a	b
0																														
1																									3.0			1.3		
2																									2.9			3		
3							28																		5.7			5.9		
4							62																		7.0			9		
5							64												30						10.3			10		
6							76						27						37			19			10.2			12		
7							90			27			30						52			29			15.9			15		
8							115			33			37						59			40			17.1			16	10	
9							148			51			50			27			62			53			19	80		17		
10							157			44			48			29			74			53			20.5			22		
11							157			58			54			35			84			64			22.8			21		
12							165	70	10	64	90		69			40			86	90		66		50	23.7			26		
13							171			80			75			39			94			75			26.5			26		
14							174		80	85			77			39			105			80			26.8			30		
15							175			125			83			59			112			85			32.2			29		
16							181			111			88			60			117			96			34.1			31		
17							185			141			95	70		60			126			100			37.2			35		
18							185			147			96			67			130			117			40			35		
19	94.9						191			152			107			71			139			118			40.6			40		
20	94						188			157			109			75			146			124			40			43		
21	88						197			161			117			82			152			132			46			42		
22	110						197			165			121			84			165			139			48			46		
23	116						200			170			124			88			173			146			49			48		
24	119						205			173			137			94			174			156			50			49		
25	129						209			179			137			104			183			159			51			52		
26	144						211			181			140			108			192			168			54			54		
27	171			91			214			187			146			111			199			174			49			62		
28	163		80	68			215			193			153			114			206			179			58			57		
29	186			77			221			195			154			122			212			191			61			62		
30	200			85			226			199			159			127			221			198			63			62		

~ 180 nm hp ~

	Mode	Pixel	Algorithm	Sensitivity	#runs
a	DDR	P90	UPA	high	10

No	0		1		2		3		4		5		6		7		8		9	
	pin hole		line cut		bridge		bridge		1x1 clear extension		1x1 opaque extension		1x2 clear extension		1x2 opaque extension		small CD		large CD	
	size	a	size	a	size	a	size	a	size	a	size	a	size	a	size	a	size	a	size	a
0																				
1																	4.0		1.8	
2					29												5.1		2.4	
3					42												9.3		6.1	
4					52												9.5		7.8	
5					62				21				29				13.2		7.0	
6					76		22		22				33		33		13.1		12.4	
7					117		21		37				45		39		16.6		13.3	
8					125		35		46				62		40		18.6		15.0	
9					131		52		49		35		68		52		20.6		19.4	
10					137		53		51		25		72		53		22.9		21.1	
11					137		54		58		41		83		67	30	24.9		23.1	
12					143	20	64		65		42		87		72		26.8		24	
13					145	50	87		78		39		93		74		28.9		26.4	
14	38				148		105		79	10	41		103		86		31.7		29.4	
15	56				152		112		84	80	53		109		96		33.1		30.4	
16	112				154		119		89	10	56		114		100		37.1		32.4	
17	135				156		126		93		62		127		105		39.4		33.4	
18	140				158		129		101		63	20	131		112		40.6		37.6	
19	143				159		133		103		71		142		117		41.3		40.7	
20	156				164		140		109		74		146		127		44		41	
21	156				164		145		115		80		157		132		48		43	
22	160		26	40	165		150		122		85		182		140		51		45	
23	161		95		168		151		130		92		202		149		49		47	
24	165		119		172		160		156		95		207		153		52		49	
25	169		128		171		157		164		103		213		162		57		52	
26	176		137		174		165		167		107		220		185		60		55	
27	177		150		176		163		173		118		224		196		60		56	
28	180		154		177		169		175		124		227		218		63		59	
29	181		162		183		169		179		153		236		228		65		61	
30	190		164		183		180		183		164		236		229		69		63	

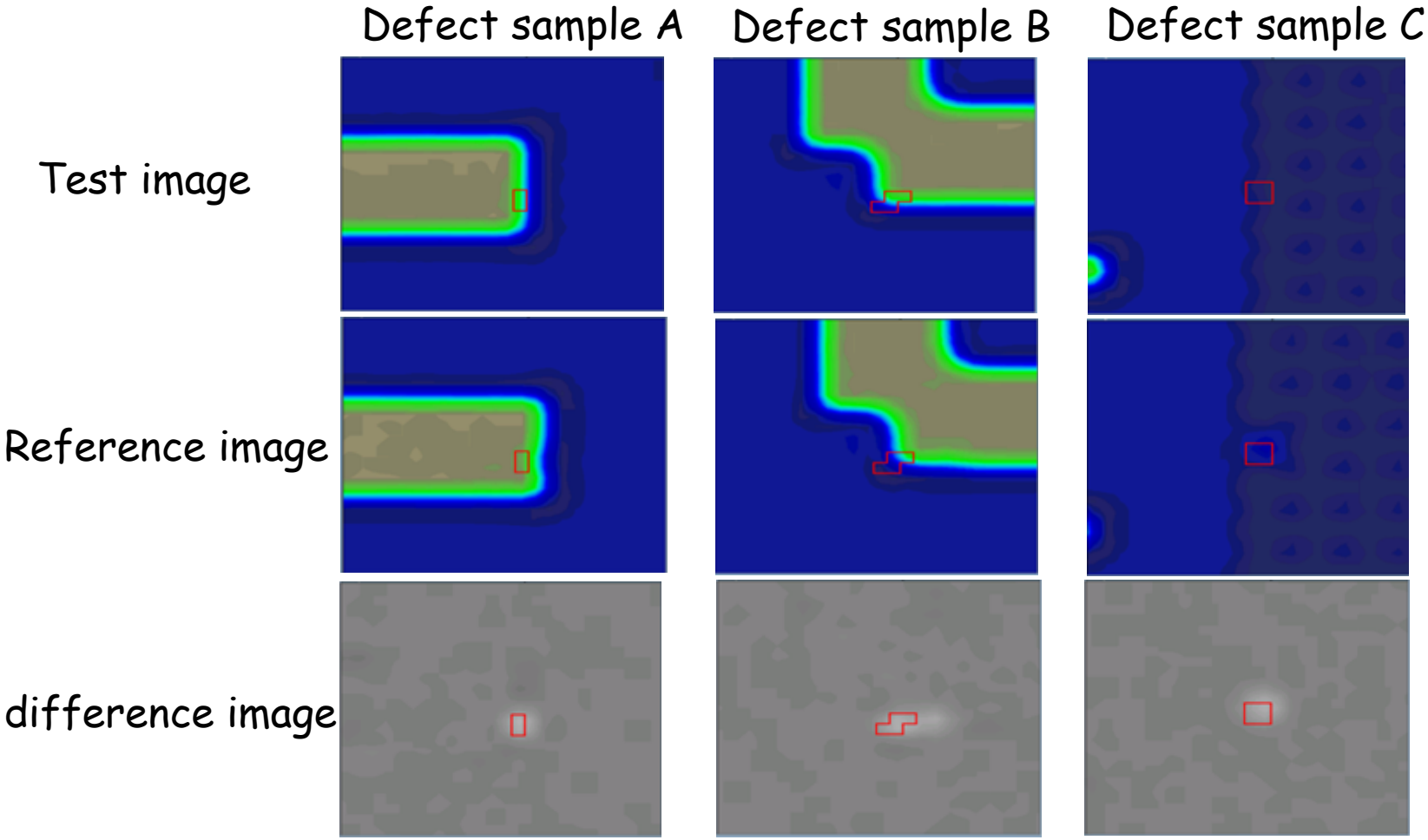
Sensitivity difference between hp260nm to hp180nm



- Inspection sensitivity of hp180nm pattern is slightly lower than hp 260nm pattern
- Inspection sensitivity of Ru capping sample is close to Si capping sample.

DUV review images of real defect

Sample Si capping w/o buffer / Inspection mode : DDR

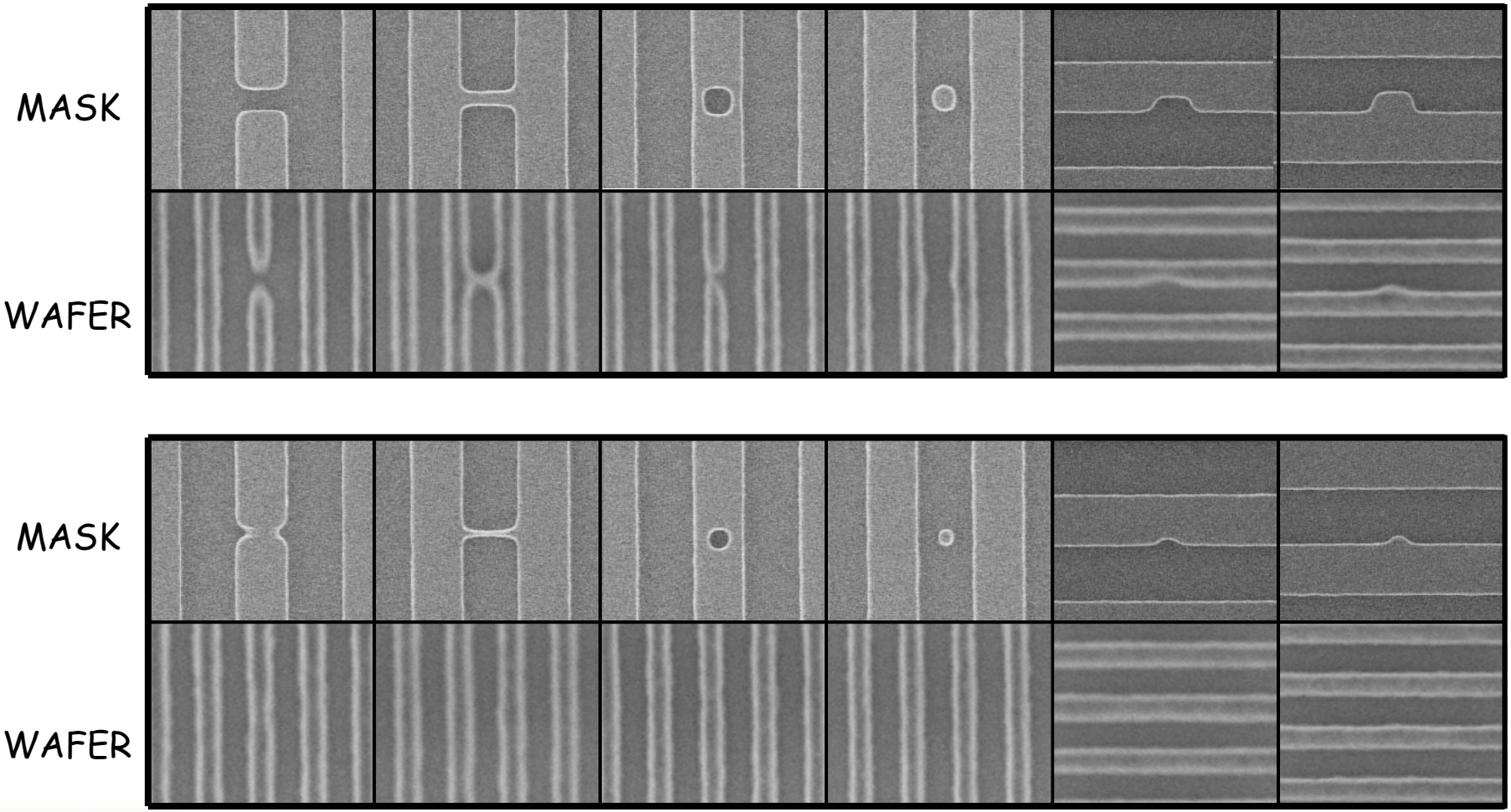


(Opaque defect exist at reference image)

Naturally occurring clear defects were not observed.

Wafer print samples of program defect

Main pattern size 325nm hp on mask (65nm on wafer)



Wafer print images : ASET

Summary

- EUV mask defect inspection was evaluated using current DUV inspection tool.
  - DUV inspection tool has potential for EUV mask defect inspection.
    (Need sensitivity improvement for 3X nm node and beyond)
  - Inspection sensitivity difference was not observed between w/ and w/o buffer surface.
  - Defect sensitivity of hp180nm pattern was slightly lower than hp 260nm pattern.
  - Inspection sensitivity of Ru capping sample was close to Si capping sample.

Future work

- Defect inspection using smaller pixel size / shorter wave length light

Acknowledgement

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- ASET, SEMATECH and LBNL for wafer print data of program defect